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Orbit Optimization and Scattering Coefficient Analysis for the Proposed GLORIA System

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Glenn Research Center, Cleveland, Ohio

December 2004

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Acknowledgments

Many thanks to Dr. Obed Scott Sands for discussion and insight in obtaining resources, and proper calculation techniques used in this analysis.

This report is a formal draft or working paper, intended to solicit comments and ideas from a technical peer group.

This report contains preliminary findings, subject to revision as analysis proceeds.

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Orbit Optimization and Scattering Coefficient Analysis for the Proposed GLORIA System

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Abstract

This paper investigates the optimization of an orbit for a Low-Earth Orbiting (LEO) satellite for coastal coverage over Antarctic and United States shorelines as part of the Geostationary/Low-Earth Orbiting Radar Image Acquisition (GLORIA) System. Simulations over a range of orbital parameters are performed to determine the optimal orbit. Scattering coefficients are computed for the optimal orbit throughout the day and characterized to compare various scenarios for which link budget comparisons could then be made.

Introduction

The Geostationary/Low-Earth Orbiting Radar Image Acquisition (GLORIA) System, which is under investigation by the University of Michigan in response to the NASA NRA 02–OES–03, proposes a constellation of Geostationary (GEO) and Low-Earth Orbit (LEO) satellites to collect daily observations for monitoring new classes of oceanic phenomena. Such phenomena include inertial waves, internal tides, surface tides, synoptic storms, and plankton migration. Within this system, the transmitter sensors are located on the GEO platforms, while the receiver sensors are located on the LEO satellites. This setup brings about a bistatic geometry that can exploit advantages in the scattering coefficient. Bistatic geometry is the setup in radar in which the transmitter and receiver are not spatially colocated. The use of bistatic geometry for the sensor system can result in increases of several dB in scattering coefficient over what is observed for an equivalently powered and oriented monostatic system. A monostatic geometry spatially colocates the transmitter and receiver. For a stationary receiver Signal-to-Noise Ratio (SNR), an increase in scattering coefficient can provide reduction in required transmitter power, antenna aperture, or receiver sensitivity.

In this memo, orbital parameters for the LEO spacecraft are varied to determine the optimal orbit for coverage over the Antarctic and United States shorelines, independent of each other. This is accomplished by propagating satellite orbits to obtain the satellite locations. Satellite position vectors along with sensor pointing vectors are used to calculate the percentage of the shoreline data points that are viewed at least once. Scattering coefficients are computed for each scenario for the purpose of future link budget comparisons.

Setup

The GLORIA system proposes a constellation of GEO and LEO satellites to make daily observations for Earth science measurements. The GEO satellites are defined at orbital slots at 60°E, 120°E, 90°W, and 20°W [1]. The LEO satellites are to have a proposed altitude between 500 and 1500km with a single day repeatable ground trace [1]. They are to contain sensors that are side-viewing with a swath-width of 100 to 800km [1]. These parameters lead to LEO satellites with 13 or 14 revolutions per day to meet the altitude specifications. The orbital parameters are set with an epoch of October 1, 2003 at 00:00:00.00 GMT.

The determination of shoreline coverage requires a database of shoreline data points [2]. Global coastal points were extracted and contained a data set of 58,196 latitude and longitude points. Figure A.1 in appendix A shows the plot of the global shoreline data set. Figure A.2 shows the plot of the Antarctic shoreline, having a data set of 1791 points. Figure A.3 shows the plot of the United States shoreline, containing 5273 data points.

There were three scenarios for this analysis. The first scenario is the baseline LEO/GEO constellation, proposed in [1]. In performing the orbit analysis, only a single LEO satellite orbit is optimized, given the assumption that other LEO satellites would orbit at the same inclination but vary their mean anomaly and right ascension to form a uniform constellation.

The second scenario looks at the optimal orbit for the baseline GEO/LEO case, but with the transmitter sensor colocated with the receiver sensor. Doing this will make the system monostatic, as opposed to the bistatic nature of

having the transmitter and receiver spatially separated. This comparison was suggested due to the high cost of launching a GEO satellite along with the required transmitter power to operate such a system.

The third scenario looks first at the results of the scattering coefficient equations to determine what the optimal pointing for the transmitter/receiver sensor pair would be, and then to optimize the constellation of the two LEOs to match such a pointing configuration. This scenario looks to find further improvements from eliminating the GEO element of the system, while keeping the bistatic nature of the system.

The scattering coefficient that has been mentioned previously is appropriate for a scattering model for a relatively damp and rough soil. Parameters for the surface type are taken from a very rough surface, S4, in [3]. Due to the frequency in question with the surface type, the Small Perturbation Method is used to solve the scattering equations, with the solution provided by Sarabandi in [4]. It is noted that a soil-specific model was chosen due to time constraints, and that a model for sea-ice, ocean surfaces, and glacial-ice would be more appropriate, though such a model is lacking [5]. It is not anticipated that the model selected will inhibit the results to a significant degree.

Baseline GEO/LEO Scenario

In the baseline scenario described for the GLORIA project [1], an optimal orbit was determined for both the Antarctic and United States shorelines, independent of each other. For each shoreline case, orbital positions are computed for each second during a single day. The orbits are required to have a certain altitude range, so the mean motion was restricted to either 13 or 14 revolutions per day. In order to cover the data points, inclinations were assumed to be between 60° and 120°, with a variation of 0.1°. All orbits were also assumed to be circular. Finally, since the orbits will repeat on a daily cycle, it was assumed that the time of day that the orbit crosses any given point is not important, so the mean anomaly was set to be zero.

Shoreline data points within view of the receiver sensor are assumed to be in view of the transmitter sensor. The receiver sensor will be pointed at a 90° azimuth angle, 40° elevation angle, tangent to the plane of motion. The beam illuminated on the ground has dimensions of 800 by 50 km in length, with the 800 km length being perpendicular to the velocity vector of the satellite.

For each second throughout the day, the orbit position will be estimated using the SDP4/SGP4 modules from the predict.c code from [6]. Using MATLAB® software, each shoreline data point will be evaluated for coverage from that satellite position. Orbits are varied first by inclination in the range of 60° to 120°, in 0.1° increments, for a mean motion of 13 revolutions per day, and then for 14 revolutions per day (up to 145° for the United States shoreline). This all assumes that the Right Ascension of the Ascending Node (RAAN) is set to 0°. The results for coverage for the Antarctic shoreline are shown in figure 1, while the United States shoreline results are shown in figure 2. In both figures, blue lines represent coverage for 13 revolutions per day, while red lines represent 14 revolutions per day. Units on the x-axis are the index of the number of increments from the starting inclination of 60°.

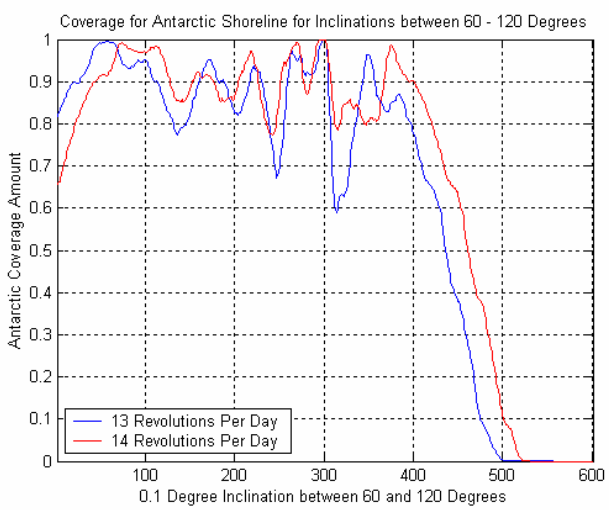

Figure 1.—Antarctic shoreline—varied inclination.

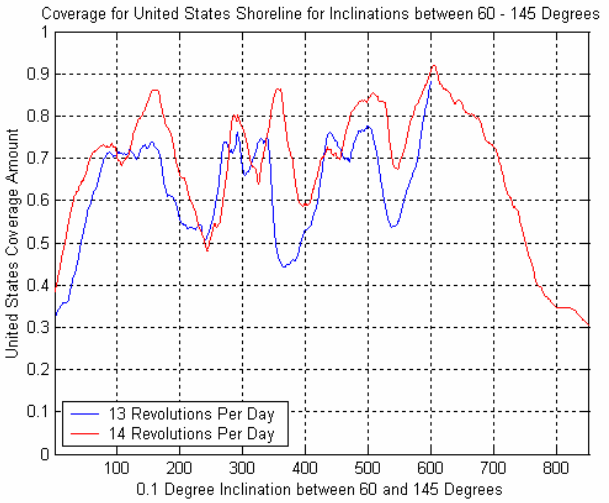

Figure 2.—United States shoreline—varied inclination.

These two figures provide information for the optimal inclinations for RAAN values equal to zero degrees. For the Antarctic shoreline, the peak inclination chosen was at 90° at a mean motion of 14 revolutions per day, which provided 100 percent coverage. The actual mean motion value of 14 was slightly modified to a value of 14.0471 revolutions per day, so that the orbits repeat their ground trace for the 90° inclination. For the United States shoreline, the peak inclination was 120.4° with 14 revolutions per day, which provided 91.98 percent coverage, which was also modified to a value of 14.0471 revolutions per day.

The RAAN angle is then varied in a range of 0° to 36°, in 0.1° increments, for the Antarctic shoreline and 0° to 60°, in 0.1° increments, for the United States shoreline. The reason that the maximum RAAN analyzed was 36°(Antarctic)/60°(U.S.) was due to the repetition of the results because of the orbits being repeatable ground traces and the geometry of the points being observed. This repetition was observed from early simulations, which were allowed to run for longer periods of time for all values of RAAN. The results from this variation in the RAAN are shown in figure 3 for the Antarctic shoreline and in figure 4 for the United States shoreline. Units on the x-axis are the index of the number of increments from the starting RAAN of 0°.

The optimal RAAN values produced from these simulations are 0° for the Antarctic shoreline and 53° for the United States shoreline. These RAAN values produced 100 percent coverage for the Antarctic shoreline and 93.15 percent coverage for the United States shoreline. Figures 5 and 6 plot the viewed versus unviewed shoreline points for the optimal orbits for the Antarctic and United States shorelines, respectfully. Points plotted in blue are unviewed points and points plotted in red are viewed at least one time a day.

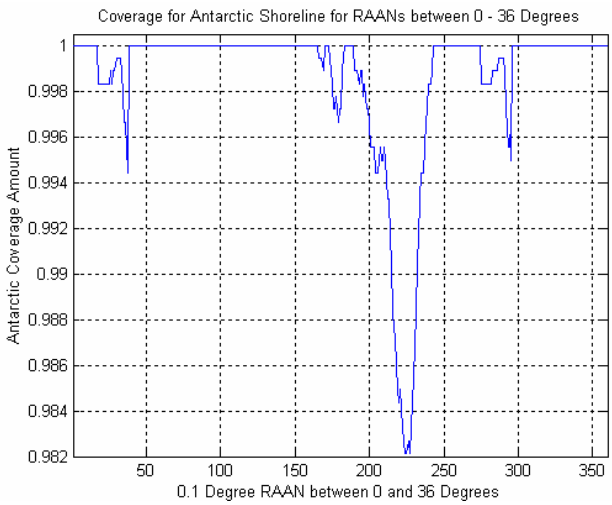

Figure 3.—Antarctic shoreline—varied RAAN.

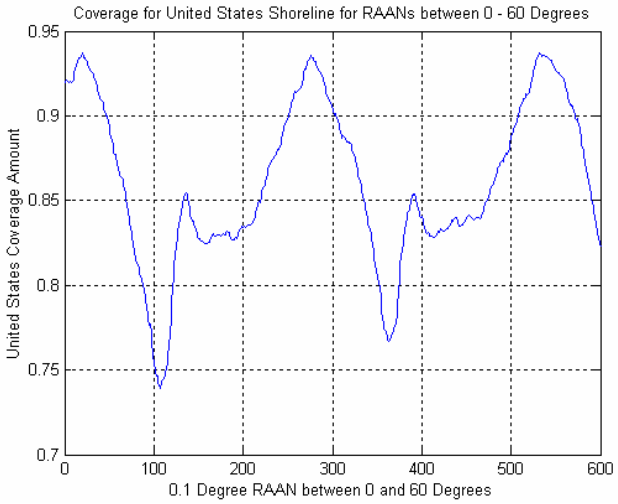

Figure 4.—United States shoreline—varied RAAN.

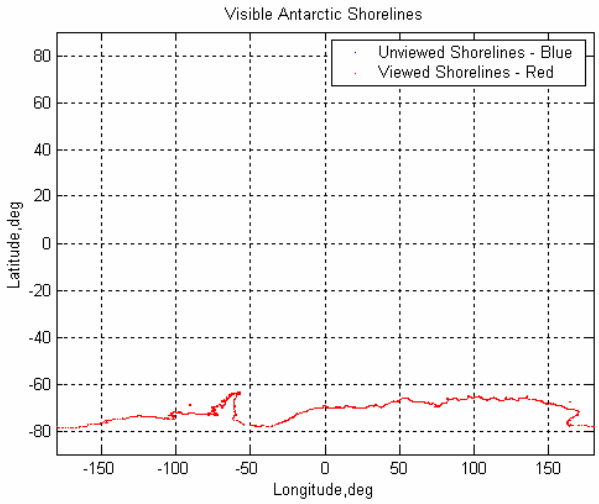

Figure 5.—Antarctic shoreline—viewed versus unviewed shorelines.

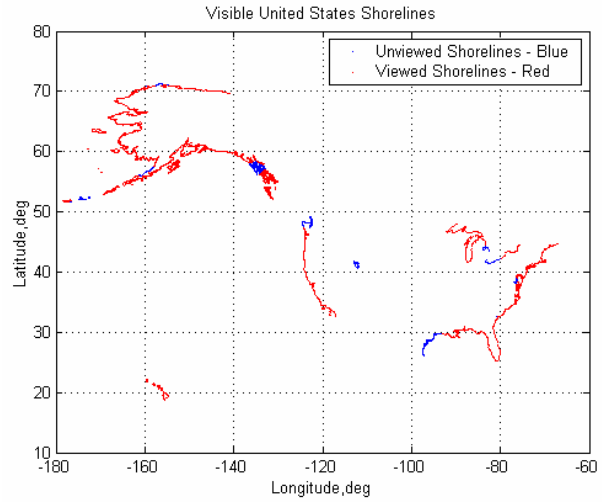

Figure 6.—United States shoreline—viewed versus unviewed shorelines.

Table 1 lists the final orbital parameters for both shorelines as a result of varying the Inclination and RAAN.

TABLE 1.—ORBITAL PARAMETERS—SCENARIO 1

Parameter	Antarctic	United States
Inclination (deg)	90°	120.4°
Mean Motion (revs/day)	14.0471	14.0471
RAAN (deg)	0°	53°
Coverage %	100%	93.15%

Using the final orbits determined above, with the location of the four GEO transmitters provided in [1], the scattering coefficient was computed for every instance that a coastal point was in view during a time period of one day. The coefficient was computed for each of the transmitter position/beam position/receiver position combinations. The beam was defined as 101 points that went along the direction perpendicular to the velocity vector. There were four possible configurations for the scattering coefficient, depending on the combination of horizontal and vertical polarizations. The two configurations that were of interest were horizontal-horizontal (hh) and vertical-vertical (vv) polarization. Computations were made using the GEO satellite that was closest to the receiver LEO satellite at each instance. Figure 7 shows the histogram of the log magnitude of the scattering coefficient for the Antarctic shoreline while figure 8 plots the histogram of the log magnitude of the scattering coefficient for the United States shoreline.

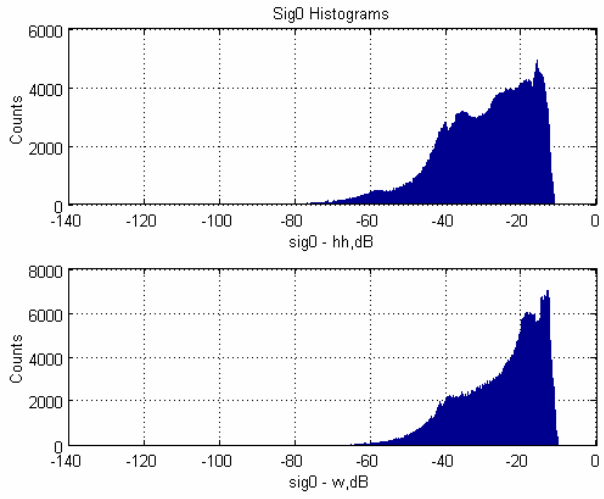

Figure 7.—Scattering coefficient—Antarctic shoreline.

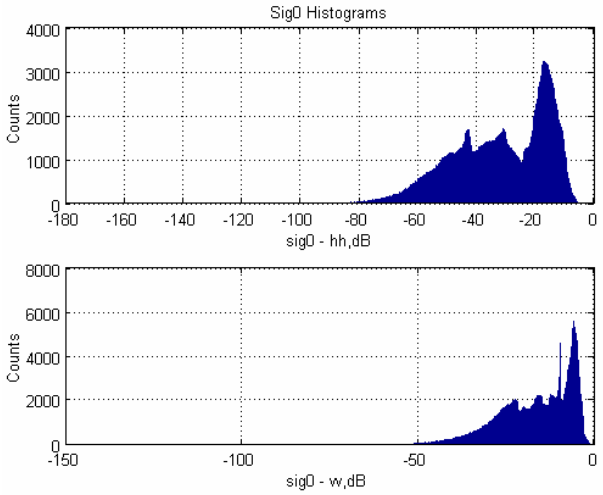

Figure 8.—Scattering coefficient—United States shoreline.

Table 2 provides a summary of the scattering coefficient based on cumulative percentiles of 5, 50, and 95 percent for each coastal region.

TABLE 2.—SCATTERING COEFFICIENT—SCENARIO 1

Region	Antarctic		United States	
hh/vv	hh	vv	hh	vv
5% (dB)	–54.7	–47.1	–61.7	–38.4
50% (dB)	–28.1	–22.8	–30.4	–14.8
95% (dB)	–14.3	–13.0	–11.8	–4.8

These scattering coefficients will be compared later with the remaining two scenarios. However, it should be recognized that the spread between the 5th and 95th percentiles were roughly 35 to 40 dB for the Antarctic shoreline and 35 to 60 dB for the United States shoreline.

Colocated LEO Scenario

In the colocated LEO scenario, the optimal receiver orbits for the Antarctic and United States shorelines remain the same as for the baseline GEO/LEO scenario. The parameters for these orbits can be found in table 1. The difference for the second scenario is that the transmitters are no longer located in GEO orbit, but rather are colocated with the receiver on the LEO satellite.

The scattering coefficients for this monostatic configuration (receiver/transmitter colocated) are computed for each instance of time that the receiver observes a coastal point. The scattering coefficient is computed for each combination of transmitter position/beam position/receiver position. Again, the beam was composed of 101 points perpendicular to the velocity

vector of the satellite. The plots of the histograms of the log magnitude of the scattering coefficients are shown in figure 9 for the Antarctic shoreline and figure 10 for the United States shoreline.

These scattering coefficients will be compared later with the other two scenarios. It should be recognized that the spread between the 5th and 95th percentiles were roughly 11 to 18 dB for the Antarctic shoreline and 6 to18 dB for the United States shoreline and roughly 30 to 40 dB higher than the proposed scenario.

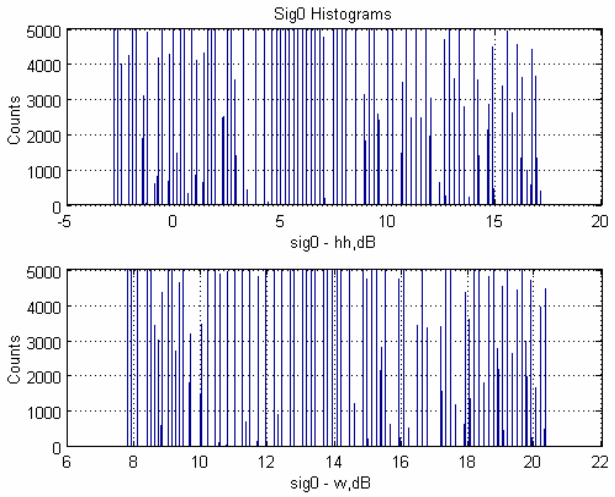

Figure 9.—Scattering coefficient—Antarctic shoreline.

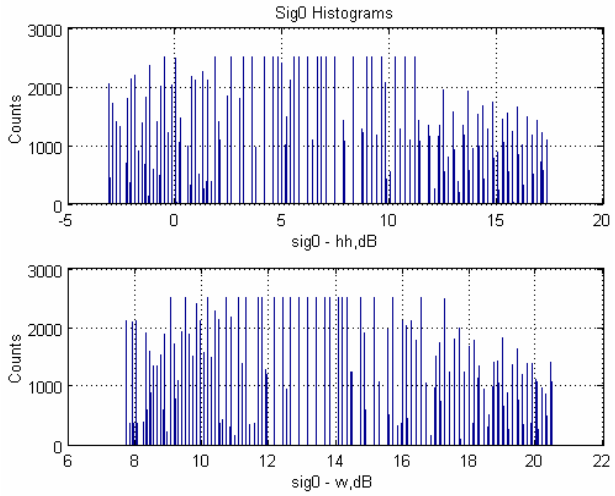

Figure 10.—Scattering coefficient—United States shoreline.

Optimized LEO Scenario

In the optimized LEO scenario, the first optimization comes from observing the patterns to the scattering coefficient based on various viewing angles. It was observed that to get high valued, low spread scattering coefficients, the configuration must be such that the signal is sent and viewed from a receiver in the geometrical plane of the direction of transmission tangent to the surface. Appendix B contains plots of the scattering coefficient for various angle configurations. Theta angles are those angles from the perpendicular of the surface tangent to the satellite, while phi angles are those from the direction of transmission along the surface tangent to the direction on reception.

From the results of the plots in appendix B, the optimum beam pointing vector would occur from a LEO/LEO formation flying satellite configuration, with the transmitter satellite leading the receiver satellite. The beam was decided to be centered on the velocity vector track but length-wise perpendicular to the track. The beam would be 800 by 200 km in size, to ensure proper integration time of the viewed signal. The receiver would be viewing the ground at an angle of 12° off the perpendicular to the surface tangent, with an azimuth of 0°. The transmitter would be viewing the ground also at an angle of 12° off the perpendicular to the surface tangent, but with an azimuth of 180°.

With the optimal beam pointing having been determined, the orbit optimization was recalculated with the new beam pointing parameters. The inclination is varied from 60° to 120°, in 0.1° increments, with a single mean motion of 14 orbits per day. Due to the fixed ground with of the beam, having more ground traces could only increase coverage. The results for coverage for the various inclinations are plotted in figure 11 for the Antarctic shoreline and in figure 12 for the United States shoreline. Again, the x-axis is the index of the number of increments from the first inclination of 60°.

Table 3 provides a summary of the scattering coefficient based on cumulative percentiles of 5, 50, and 95 percent for each coastal region.

TABLE 3.—SCATTERING COEFFICIENT—SCENARIO 2

Region	Antarctic		United States	
hh/vv	hh	vv	hh	vv
5% (dB)	–2.13	8.29	–2.26	8.24
50% (dB)	6.15	13.39	6.13	13.38
95% (dB)	15.99	19.56	16.20	14.69

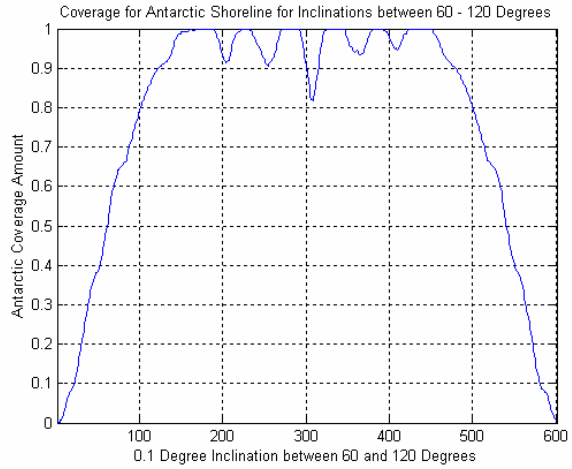

Figure 11.—Antarctic shoreline—varied inclination.

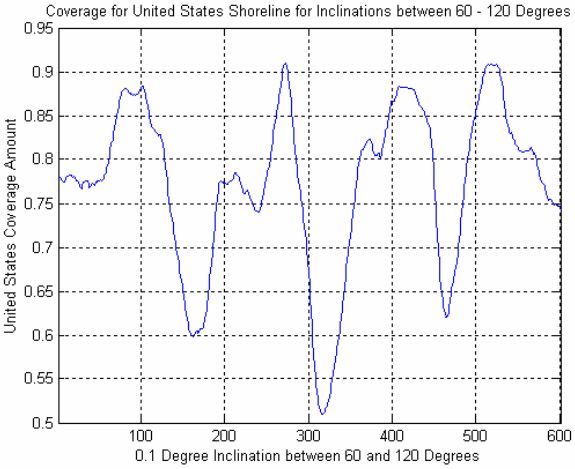

Figure 12.—United States shoreline—varied inclination.

These previous two figures provide information for the optimal inclinations for RAAN values equal to zero degrees. For the Antarctic shoreline, the peak inclination chosen was at 104.4°, which provided 100 percent coverage. The actual mean motion value of 14 was slightly modified to a value of 13.9837 revolutions per day, so that the orbits repeat their ground trace for the 104.4° inclination. For the United States shoreline, the peak inclination was 87.2°, which provided 91.96 percent coverage, which was also modified to a value of 14.0591 revolutions per day.

The RAAN angle is then varied in a range of 0° to 36°, in 0.1° increments. RAAN angle analysis is the same as in the first scenario. The results from this variation in the RAAN are shown in figure 13 for the Antarctic shoreline and in figure 14 for the United States shoreline. Again, the x-axis is the index of the number of increments from the first inclination of 0°.

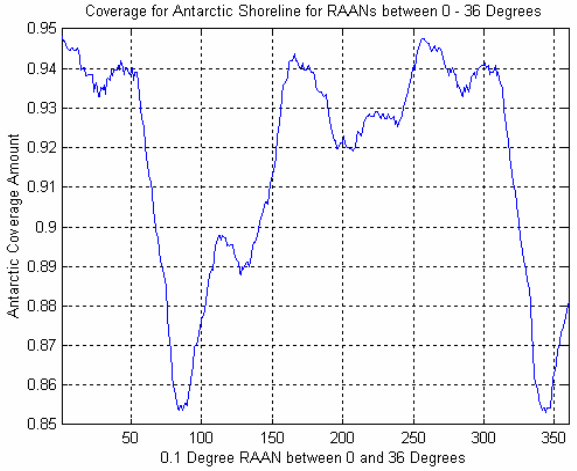

Figure 13.—Antarctic shoreline—varied RAAN.

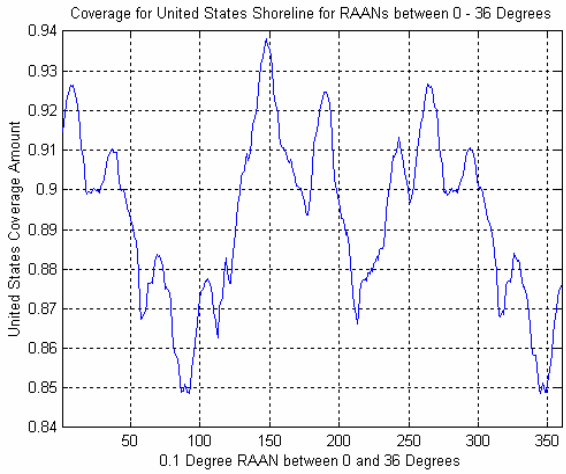

Figure 14.—United States shoreline—varied RAAN.

The optimal RAAN values produced from these simulations are 0° for the Antarctic shoreline and 14.7° for the United States shoreline. These RAAN values produced 94.81 percent coverage for the Antarctic shoreline and 94.31 percent coverage for the United States shoreline. Figures 15 and 16 plot the viewed versus unviewed shoreline points for the optimal orbits for the Antarctic and United States shorelines, respectfully. Again, points plotted in blue are unviewed points and points plotted in red are viewed at least one time a day.

Table 4 lists the final orbital parameters for both shorelines as a result of varying the Inclination and RAAN.

TABLE 4.—ORBITAL PARAMETERS—SCENARIO 3

Parameter	Antarctic	United States
Inclination (deg)	104.4°	87.2°
Mean Motion (revs/day)	13.9837	14.0591
RAAN (deg)	0°	14.7°
Coverage %	94.81%	94.31%

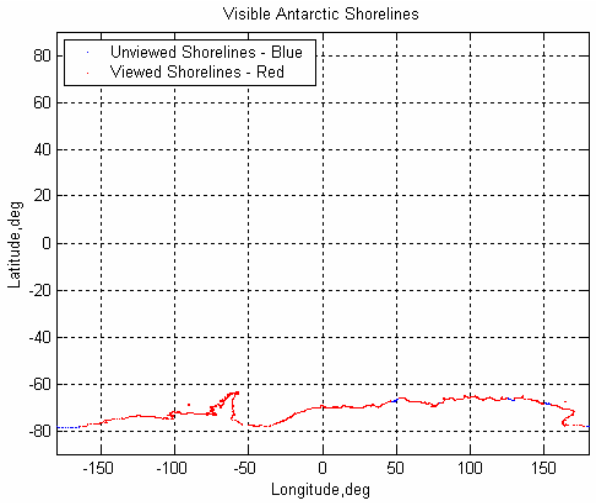

Figure 15.—Antarctic shoreline—viewed versus unviewed shorelines.

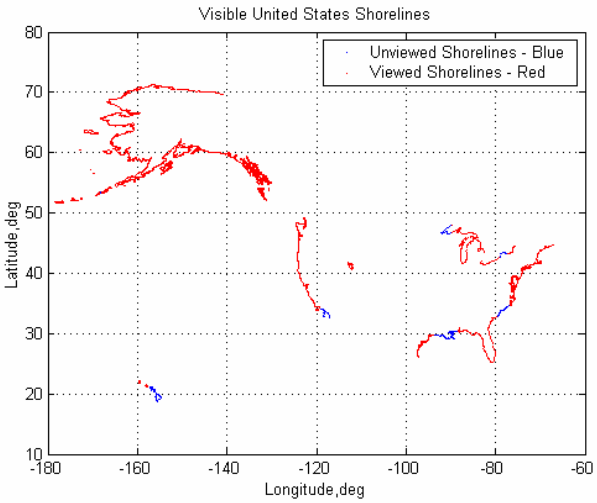

Figure 16.—United States shoreline—viewed versus unviewed shorelines.

Using the final orbits determined above, the scattering coefficients for this bistatic configuration (receiver/transmitter at two different locations) are computed for each instance of time that the receiver observes a coastal point. The scattering coefficient is computed for each combination of transmitter position/beam position/receiver position. Again, the beam was composed of 101 points perpendicular to the velocity vector of the satellite. The plots of the histograms of the log magnitude of the scattering coefficients are shown in figure 17 for the Antarctic shoreline and figure 18 for the United States shoreline.

Table 5 provides a summary of the scattering coefficient based on cumulative percentiles of 5, 50, and 95 percent for each coastal region.

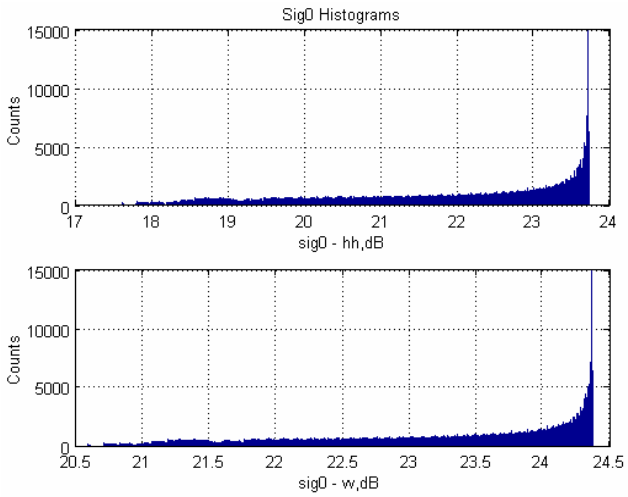

Figure 17.—Scattering coefficient—Antarctic shoreline.

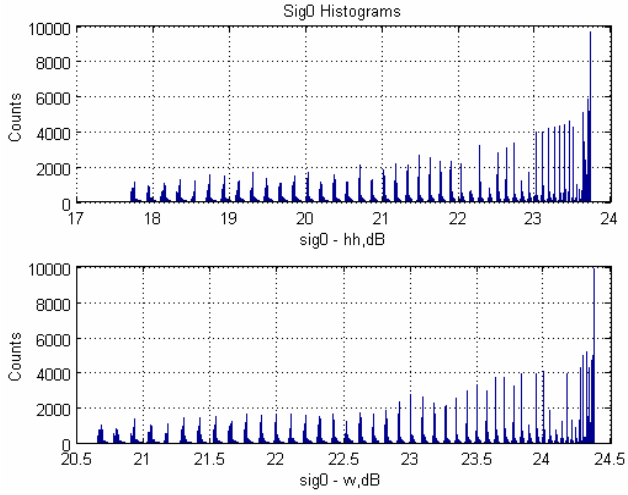

Figure 18.—Scattering coefficient—United States shoreline.

TABLE 5.—SCATTERING COEFFICIENT—SCENARIO 3

Region	Antarctic		United States	
hh/vv	hh	vv	hh	vv
5% (dB)	18.52	21.16	18.14	20.92
50% (dB)	22.14	23.41	22.02	23.33
95% (dB)	23.68	24.35	23.69	24.35

These scattering coefficients will be compared later with the previous two scenarios. However, it should be recognized that the spread between the 5th and 95th percentiles were roughly 3 to 5 dB for both the Antarctic and United States shorelines and larger than the monostatic scenario.

Conclusions and Future Work

Figures 7, 9, and 17 illustrate the scattering coefficient histogram for the three scenarios for the Antarctic region, with figures 8, 10, and 18 representing the United States shoreline region. Table 6 presents the 50th percentile scattering coefficient for each scenario along with the difference between the 95th and 5th percentiles for the Antarctic region, with table 7 making the comparison for the United States region. Figure 19 and 20 illustrate the differences in the scattering coefficient ranges for the Antarctic and United States shorelines.

TABLE 6.—ANTARCTIC SHORELINE SCATTERING COEFFICIENT COMPARISON

Category	50%		Difference	
hh/vv	hh	vv	hh	vv
Scenario 1	–28.1	–22.8	40.38	34.02
Scenario 2	6.15	13.39	18.12	11.27
Scenario 3	22.14	23.41	5.16	3.19

TABLE 7.—UNITED STATES SHORELINE SCATTERING COEFFICIENT COMPARISON

Category	50%		Difference	
hh/vv	hh	vv	hh	vv
Scenario 1	–30.4	–14.8	49.9	33.56
Scenario 2	6.13	13.38	18.46	11.45
Scenario 3	22.02	23.33	5.55	3.43

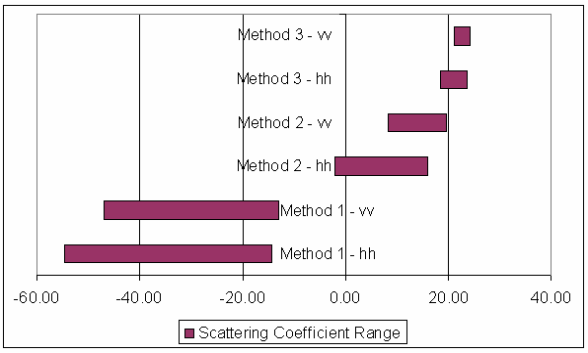

Figure 19.—Scattering coefficient ranges—Antarctic shoreline.

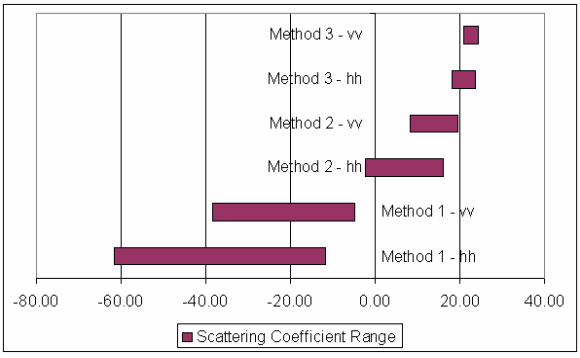

Figure 20.—Scattering coefficient ranges—United States shoreline.

From these two tables and figures, it is clear that Scenario 3 has the largest 50th percentile scattering coefficient and the smallest difference between 95th and 5th percentile scattering coefficients. Scenario 3 would therefore provide the largest average scattering coefficient gain, and maintain that gain across the beam with the least variation, meaning the overall swath of the sensor will have more uniform illumination. Also having both the transmitter and receiver in LEO orbit will allow for less required transmitter power, as would be needed for a transmitter in GEO. Another benefit of having both satellites in LEO formation flying orbits is that if only a once a day visualization is desired, then only two satellites would be needed overall for the majority of the regions of interest (94 percent coverage).

Future work in this area would be to perform a more thorough optimization for the beam pointing, with a more appropriate scattering model for the scattering coefficients. Also, other regions of the world could be analyzed for optimal orbits. Finally, link budget comparisons could be made between different scenarios to fully appreciate the benefits of the higher and more stable scattering coefficients that can be obtained through optimization of the beam pointing and orbits.

References

[1] University of Michigan, "GLORIA-Geostationary/Low-Earth Orbiting Radar Image Acquisition System: A Multi-Static GEO/LEO Synthetic Aperture Radar Satellite Constellation for Earth Observation" Proposal in response to NASA NRA 02–OES–03

[2] Sloss, P., www.ngdc.noaa.gov/mgg/shorelines/shorelines.html, February 2004.

[3] Oh, Y., Sarabandi, S., and Ulaby, F.T., "An empirical model and an inversion technique for radar scattering from bare soil surfaces," IEEE Trans. Geo., pp. 370–381, vol. 30, no. 2, March 1992.

[4] Sarabandi, K., "Kirchoff approximation and small perturbation method for gaussian and exponential surface correlation function," Unpublished manuscript, January 2004.

[5] Daout, F., Khenchaf, A., and Saillard, J., "The effect of salinity and temperature on the electromagnetic field scattered by sea water," Proc. Oceans 94, pp. I/110–I/115, 13–16 September 1994, Brest France.

[6] Magliacane, J.A., Predict: A Satellite Tracking/Orbital Prediction Program," www.qsl.net/kd2bd/predict.html, February 2004.

Appendix A
Shorelines

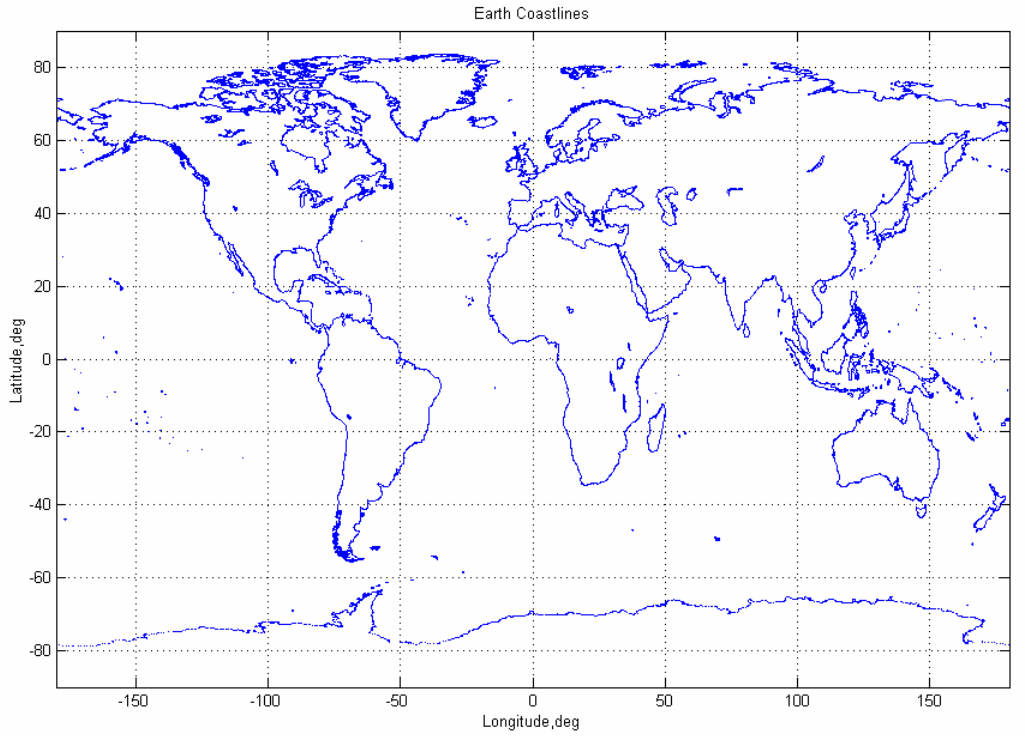

Figure A.1.—Global shoreline data set.

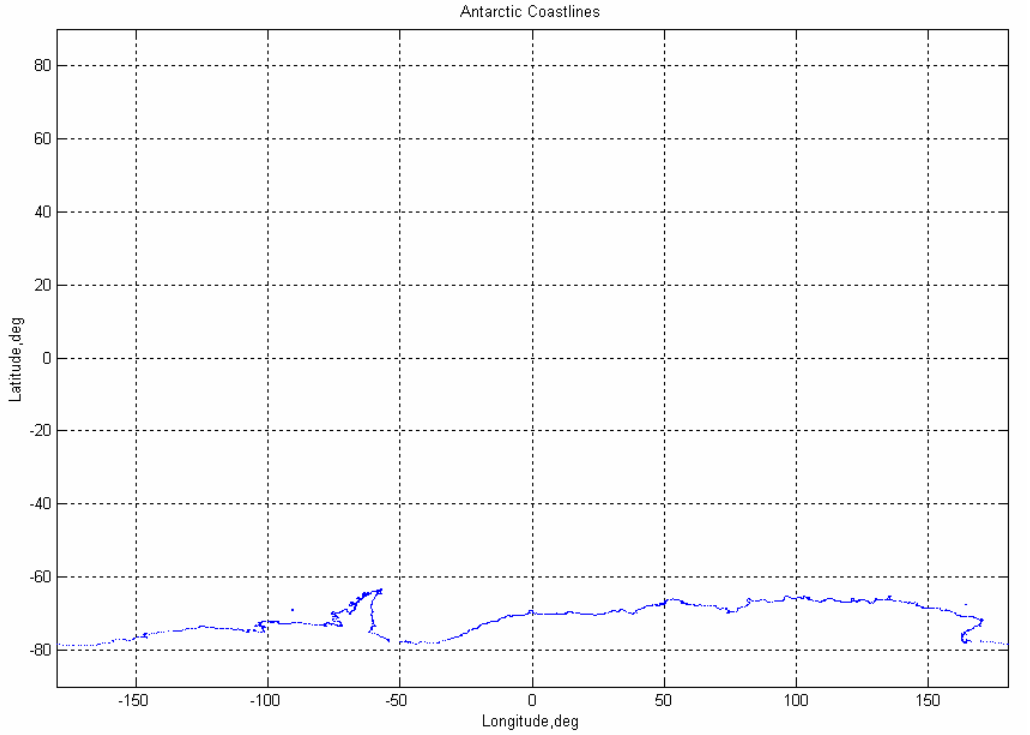

Figure A.2.—Antarctic shoreline data set.

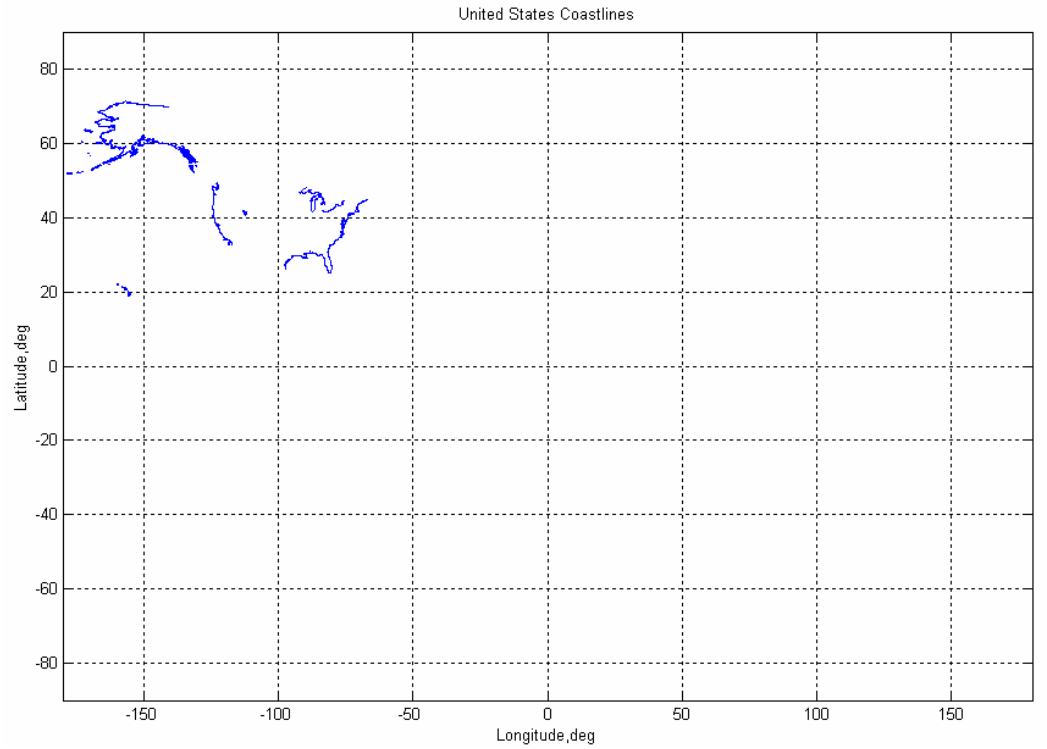

Figure A.3.—United States shoreline data set.

Appendix B
Scattering Coefficients Analysis

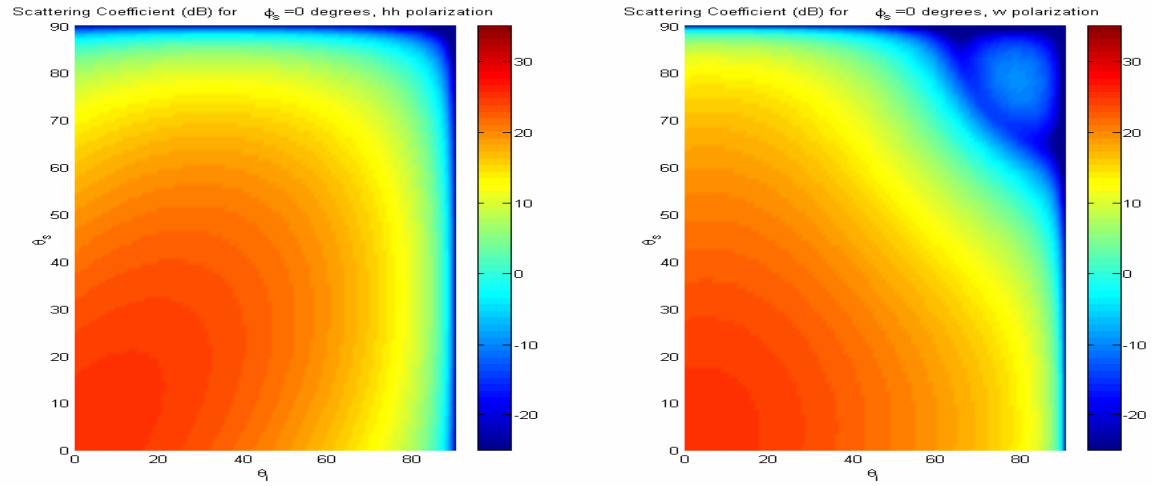

Figure B.1.—Phi scattered = 0°.

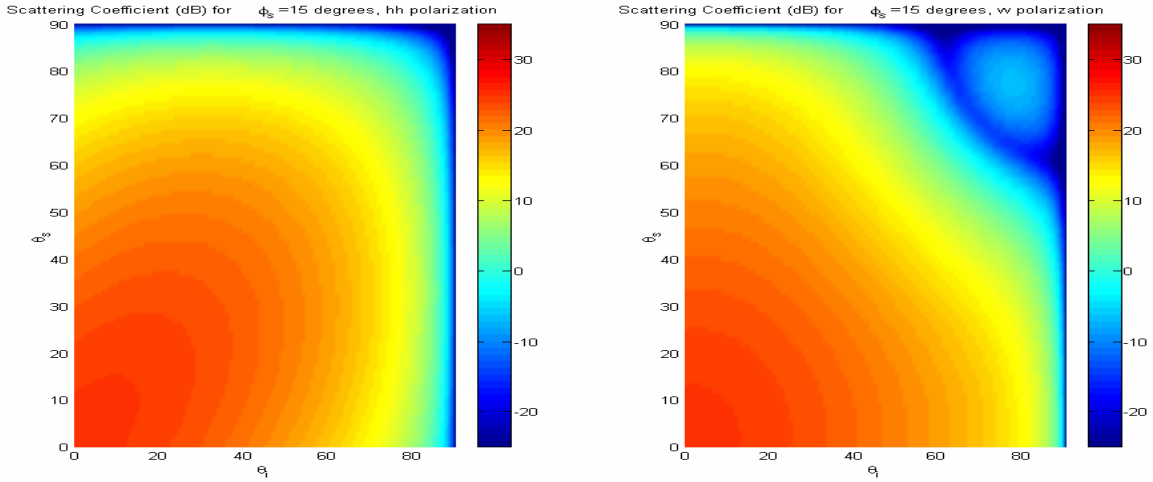

Figure B.2.—Phi scattered = 15°.

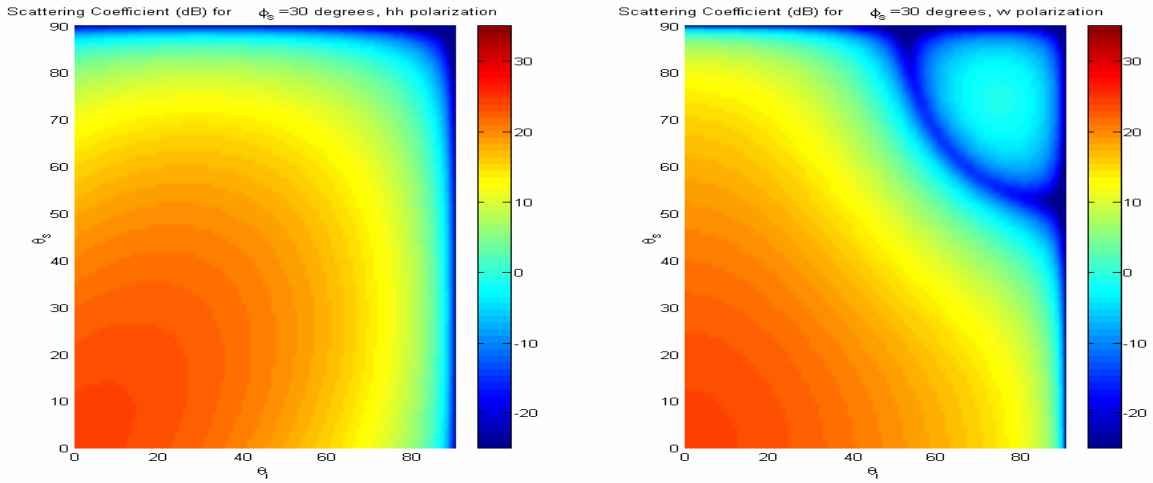

Figure B.3.—Phi scattered = 30°.

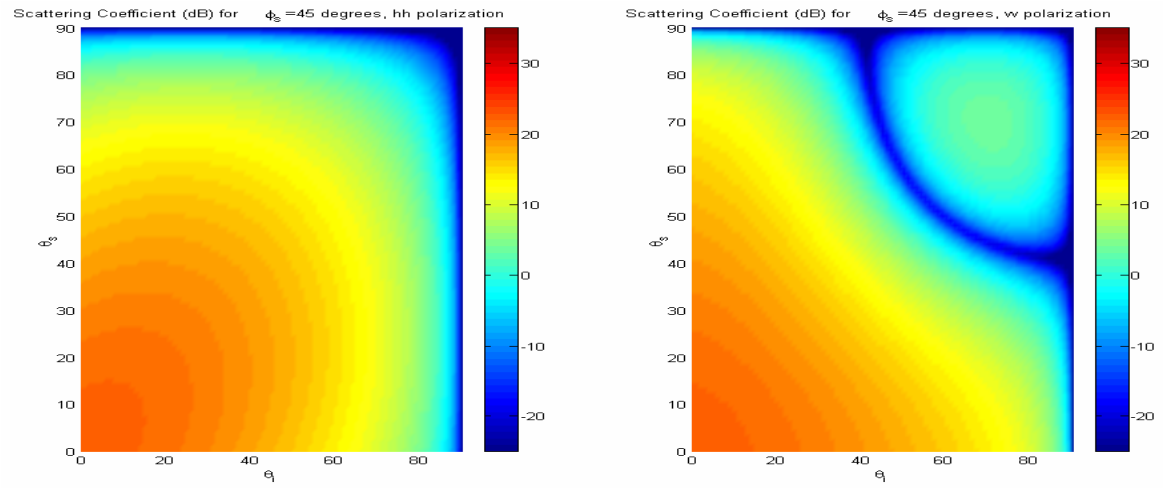

Figure B.4.—Phi scattered = 45°.

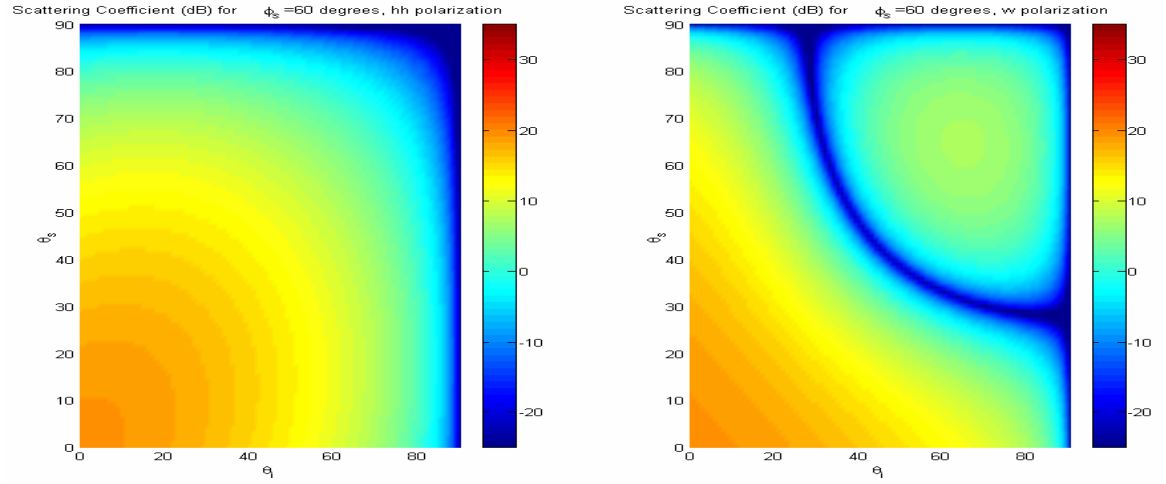

Figure B.5.—Phi scattered = 60°.

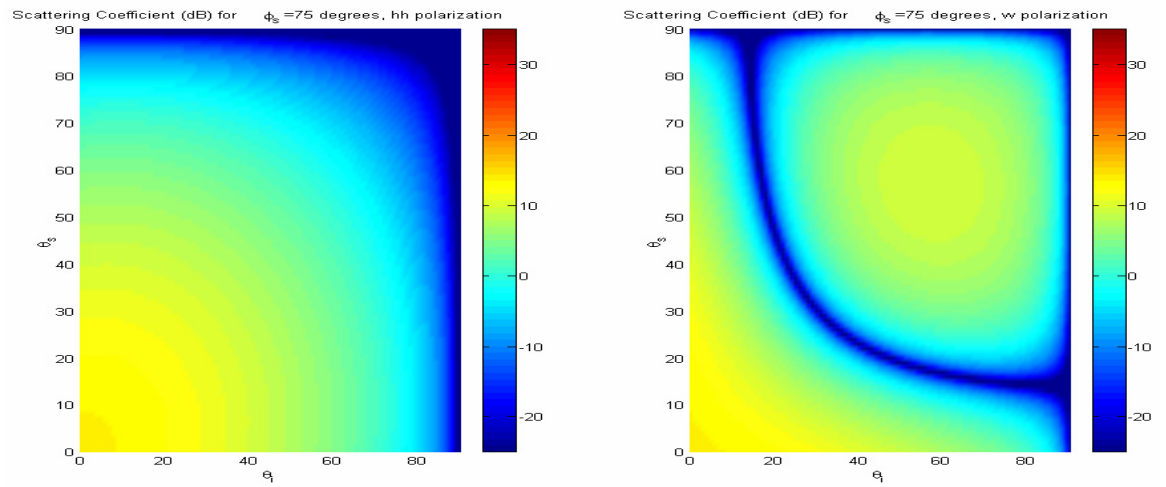

Figure B.6.—Phi scattered = 75°.

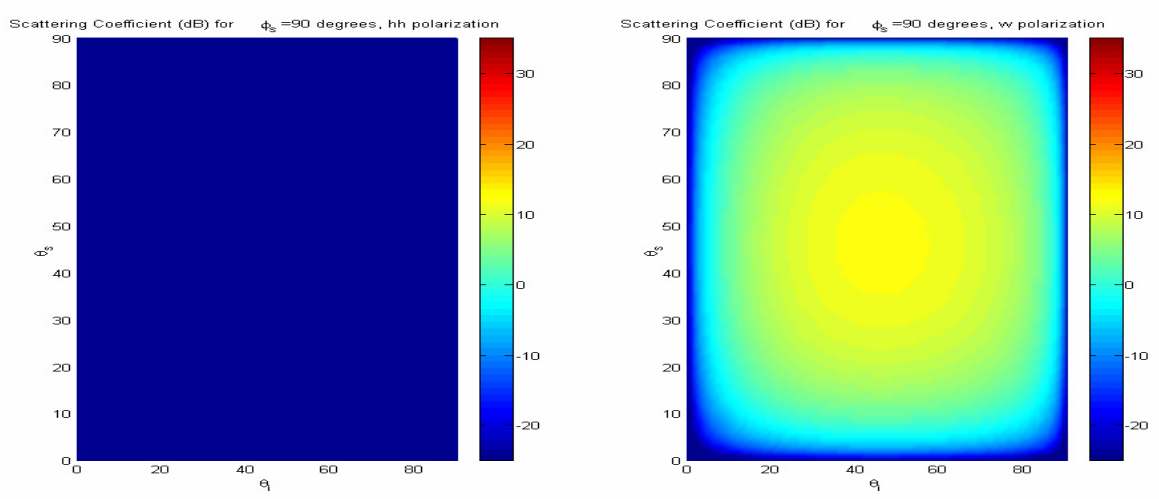

Figure B.7.—Phi scattered = 90°.

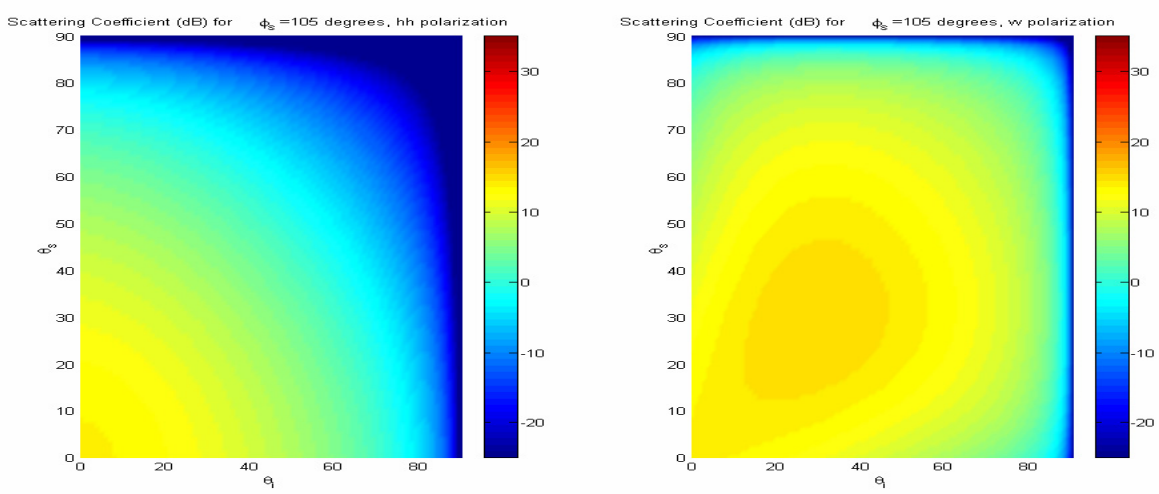

Figure B.8.—Phi scattered = 105°.

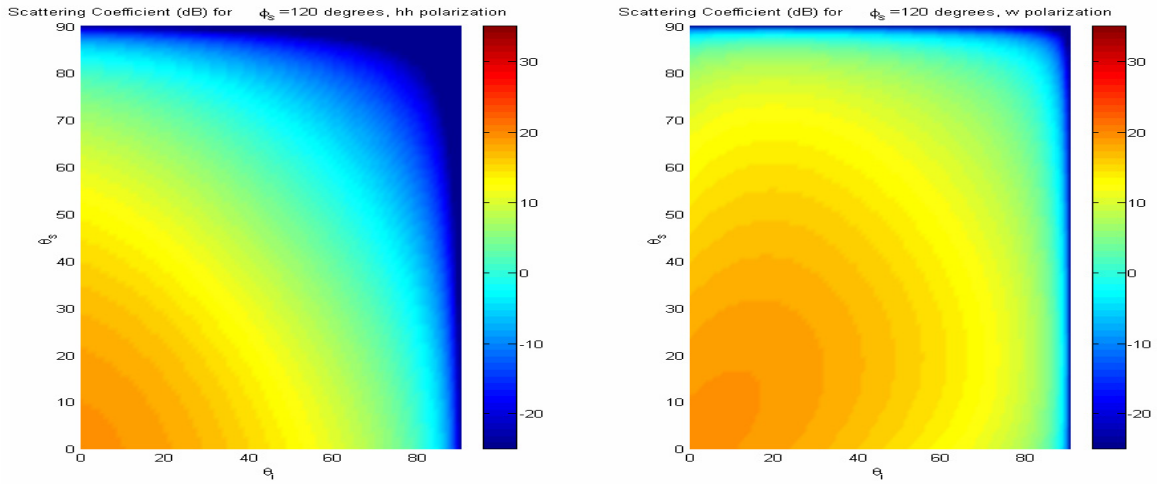

Figure B.9.—Phi scattered = 120°.

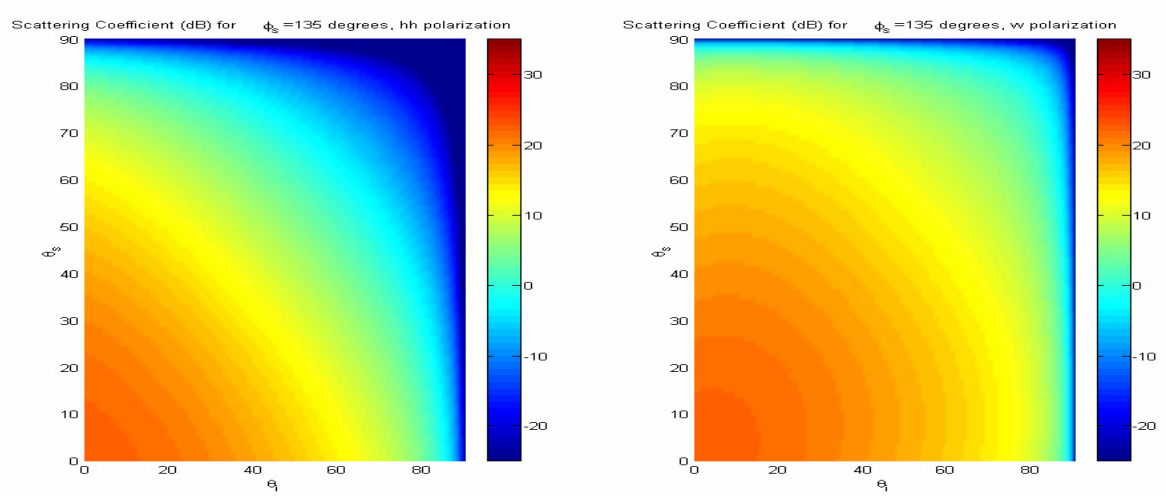

Figure B.10.—Phi scattered = 135°.

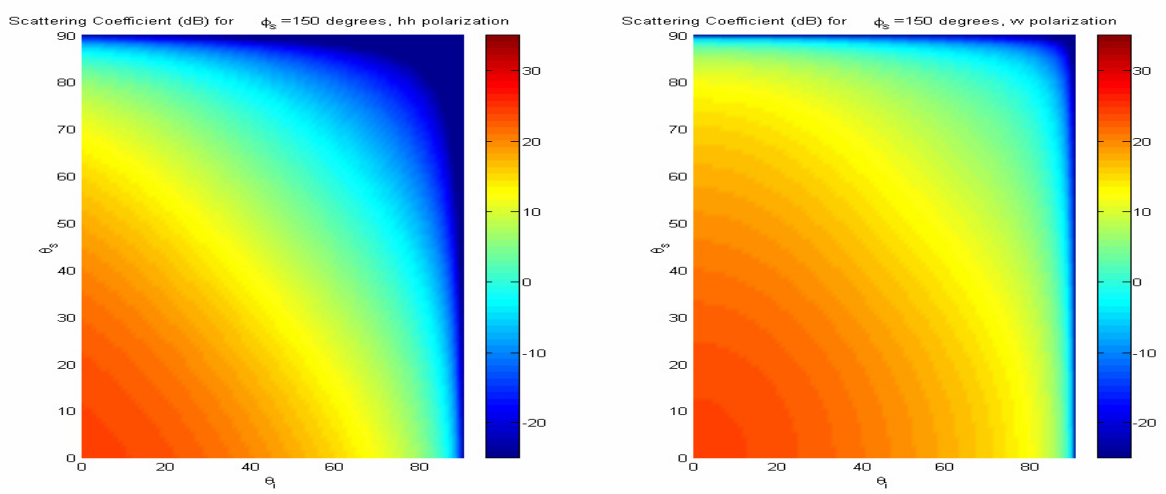

Figure B.11.—Phi scattered = 150°.

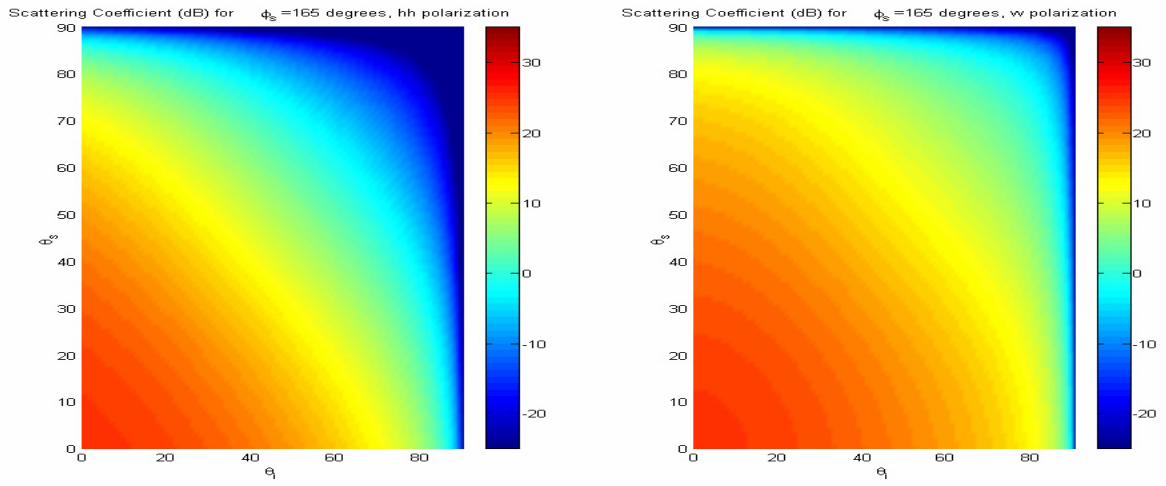

Figure B.12.—Phi scattered = 165°.

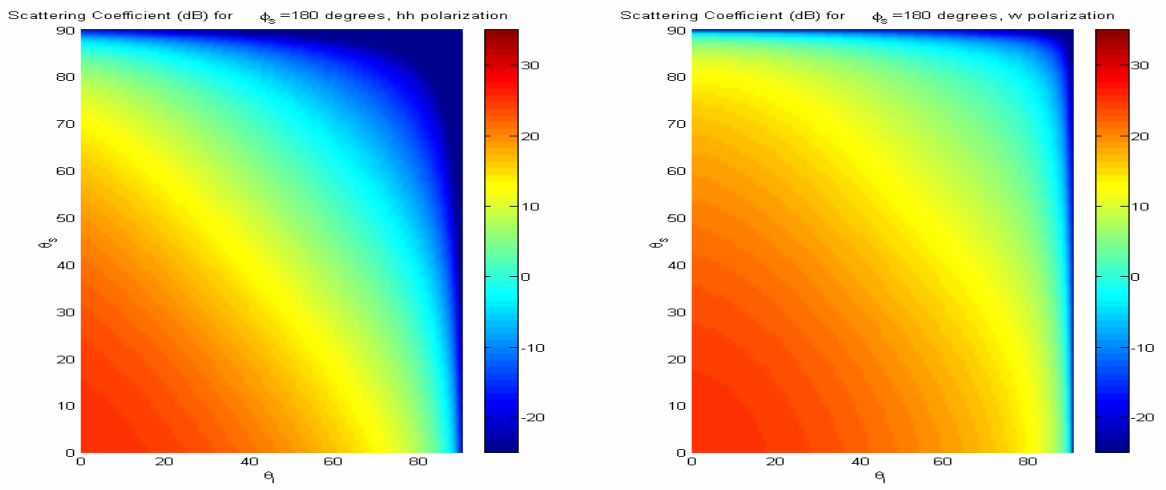

Figure B.13.—Phi scattered = 180°.

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13. ABSTRACT ***(Maximum 200 words)***

This paper investigates the optimization of an orbit for a Low-Earth Orbiting (LEO) satellite for coastal coverage over Antarctic and United States shorelines as part of the Geostationary/Low-Earth Orbiting Radar Image Acquisition (GLORIA) System. Simulations over a range of orbital parameters are performed to determine the optimal orbit. Scattering coefficients are computed for the optimal orbit throughout the day and characterized to compare various scenarios for which link budget comparisons could then be made.

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Orbit determination; Remote sensing; Low earth orbits; Orbit calculation; Multistatic radar; Bistatic reflectivity; Backward scattering; Forward scattering

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